US009166631B2

(12) **United States Patent**
Choi et al.

(10) **Patent No.: US 9,166,631 B2**
(45) **Date of Patent: Oct. 20, 2015**

(54) **SOFTWARE-DEFINED RADIO TERMINAL APPARATUS, AND METHOD FOR DISTRIBUTING AND INSTALLING RADIO APPLICATIONS**

(75) Inventors: **Seung Won Choi**, Seoul (KR); **June Kim**, Incheon-si (KR); **Chi Young Ahn**, Gyeonggi-do (KR)

(73) Assignee: **INDUSTRY-UNIVERSITY COOPERATION FOUNDATION HANYANG UNIVERSITY**, Seoul (KR)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **14/116,578**

(22) PCT Filed: **May 8, 2012**

(86) PCT No.: **PCT/KR2012/003578**

§ 371 (c)(1), (2), (4) Date: **Nov. 11, 2013**

(87) PCT Pub. No.: **WO2012/153968**

PCT Pub. Date: **Nov. 15, 2012**

(65) **Prior Publication Data**

US 2014/0064344 A1 Mar. 6, 2014

(30) **Foreign Application Priority Data**

May 9, 2011 (KR) 10-2011-0043646
May 9, 2011 (KR) 10-2011-0043680
May 9, 2011 (KR) 10-2011-0043683

(51) **Int. Cl.**

H04B 1/38	(2015.01)
H04B 1/00	(2006.01)
G06F 9/445	(2006.01)
H04W 88/02	(2009.01)
H04W 4/00	(2009.01)

(52) **U.S. Cl.**

CPC ***H04B 1/0028*** (2013.01); ***G06F 8/61*** (2013.01); ***H04W 4/001*** (2013.01); ***H04W 88/02*** (2013.01)

(58) **Field of Classification Search**

USPC 375/219–220, 222, 257; 717/140, 149, 717/178

See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

7,480,489 B2 * 1/2009 Eslick et al. 455/72
2005/0176455 A1 * 8/2005 Krishnan et al. 455/522

(Continued)

FOREIGN PATENT DOCUMENTS

JP 2006-072414 A 3/2006
WO 2010/026292 A1 3/2010
WO 2010/141448 A1 12/2010

OTHER PUBLICATIONS

International Search Report mailed Nov. 29, 2012; PCT/KR2012/003578.

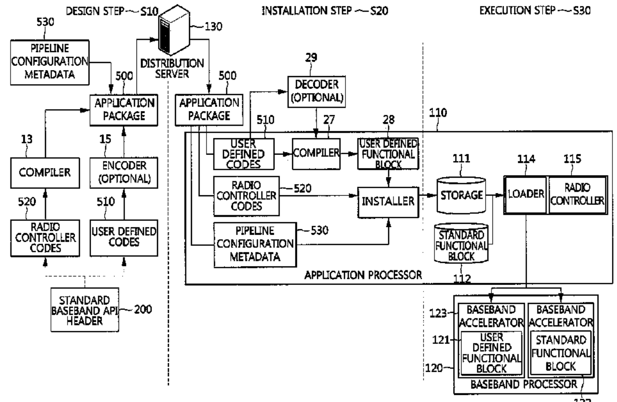
Primary Examiner — Khanh C Tran

(74) *Attorney, Agent, or Firm* — Ladas & Parry LLP

(57) **ABSTRACT**

According to the present invention, a software-defined radio terminal apparatus is a software-defined radio terminal apparatus which is adaptively constituted based on radio applications, and may comprise a storage unit, a microprocessor, and a baseband accelerator. The microprocessor reads, from the storage unit, a code, including a radio controller layer and a baseband driver layer, and executes the code, wherein the radio controller layer delivers a control command for controlling the baseband accelerator and information to be transmitted, from an upper layer to the baseband accelerator, and delivers the information received from the baseband accelerator to the upper layer, wherein the baseband driver layer provides interface between the radio controller layer and the baseband accelerator. In addition, the microprocessor is configured to load at least one functional block required for the implementation of a radio application from the storage unit to the baseband accelerator, and the functional block loaded to the baseband accelerator includes a baseband control functional block for controlling the baseband accelerator in real time.

14 Claims, 11 Drawing Sheets



(56) **References Cited**

U.S. PATENT DOCUMENTS

2006/0043164	A1*	3/2006	Dowling et al.	235/375
2009/0279699	A1	11/2009	Noda	
2011/0095826	A1*	4/2011	Hadjichristos et al.	330/279
2012/0096445	A1*	4/2012	Berg et al.	717/140
2012/0317590	A1*	12/2012	Chae et al.	719/328

* cited by examiner

FIG. 1

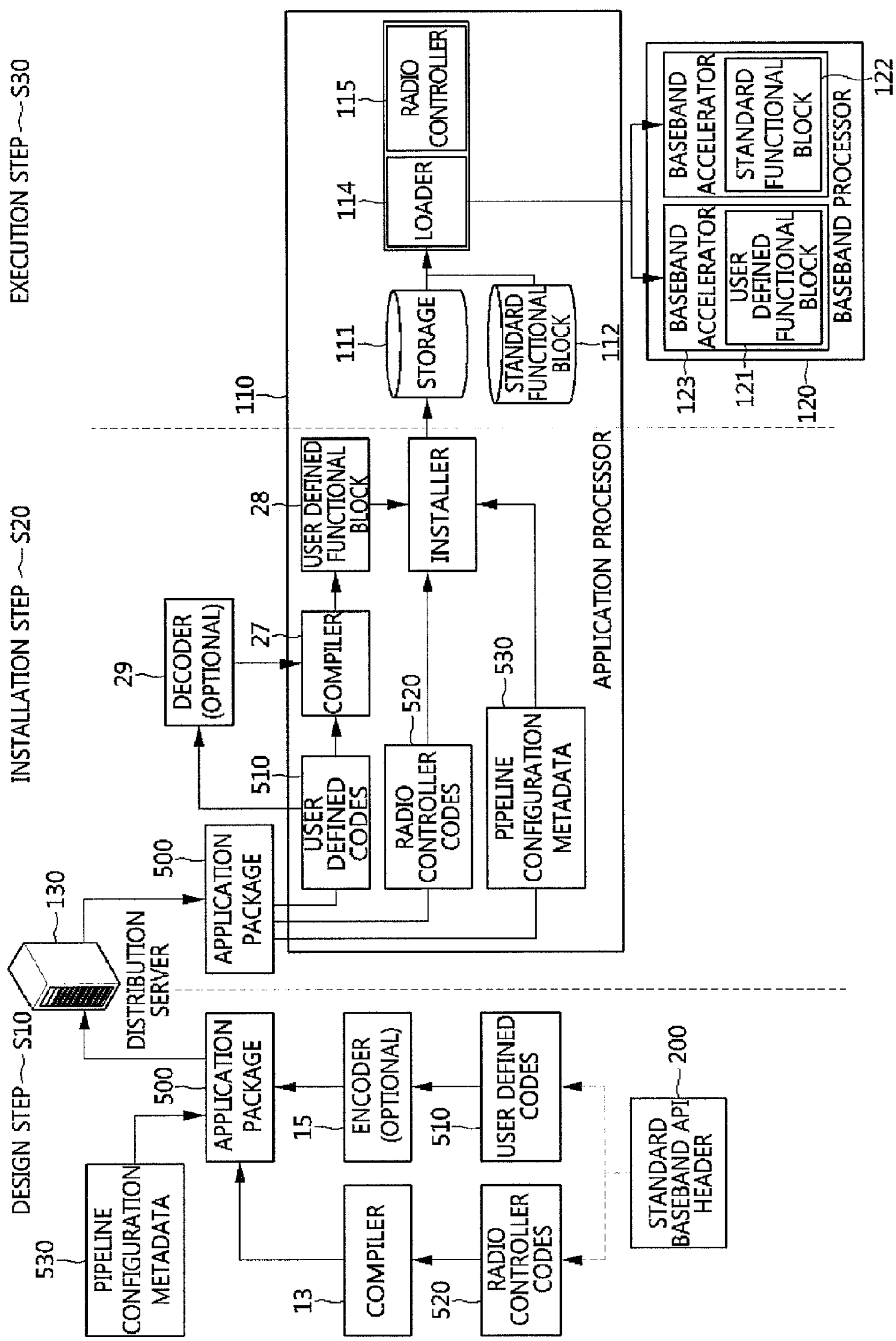

DESIGN STEP ~S10
INSTALLATION STEP ~S20
EXECUTION STEP ~S30
530
PIPELINE CONFIGURATION METADATA
500
APPLICATION PACKAGE
13
COMPILER
15
ENCODER (OPTIONAL)
520
RADIO CONTROLLER CODES
510
USER DEFINED CODES
200
STANDARD BASEBAND API HEADER
130
DISTRIBUTION SERVER
500
APPLICATION PACKAGE
510
USER DEFINED CODES
520
RADIO CONTROLLER CODES
530
PIPELINE CONFIGURATION METADATA
29
DECODER (OPTIONAL)
27
COMPILER
28
USER DEFINED FUNCTIONAL BLOCK
INSTALLER
APPLICATION PROCESSOR
110
111
STORAGE
112
STANDARD FUNCTIONAL BLOCK
114
LOADER
115
RADIO CONTROLLER
123
121
120
BASEBAND ACCELERATOR
USER DEFINED FUNCTIONAL BLOCK
BASEBAND ACCELERATOR
STANDARD FUNCTIONAL BLOCK
122
BASEBAND PROCESSOR

FIG. 2

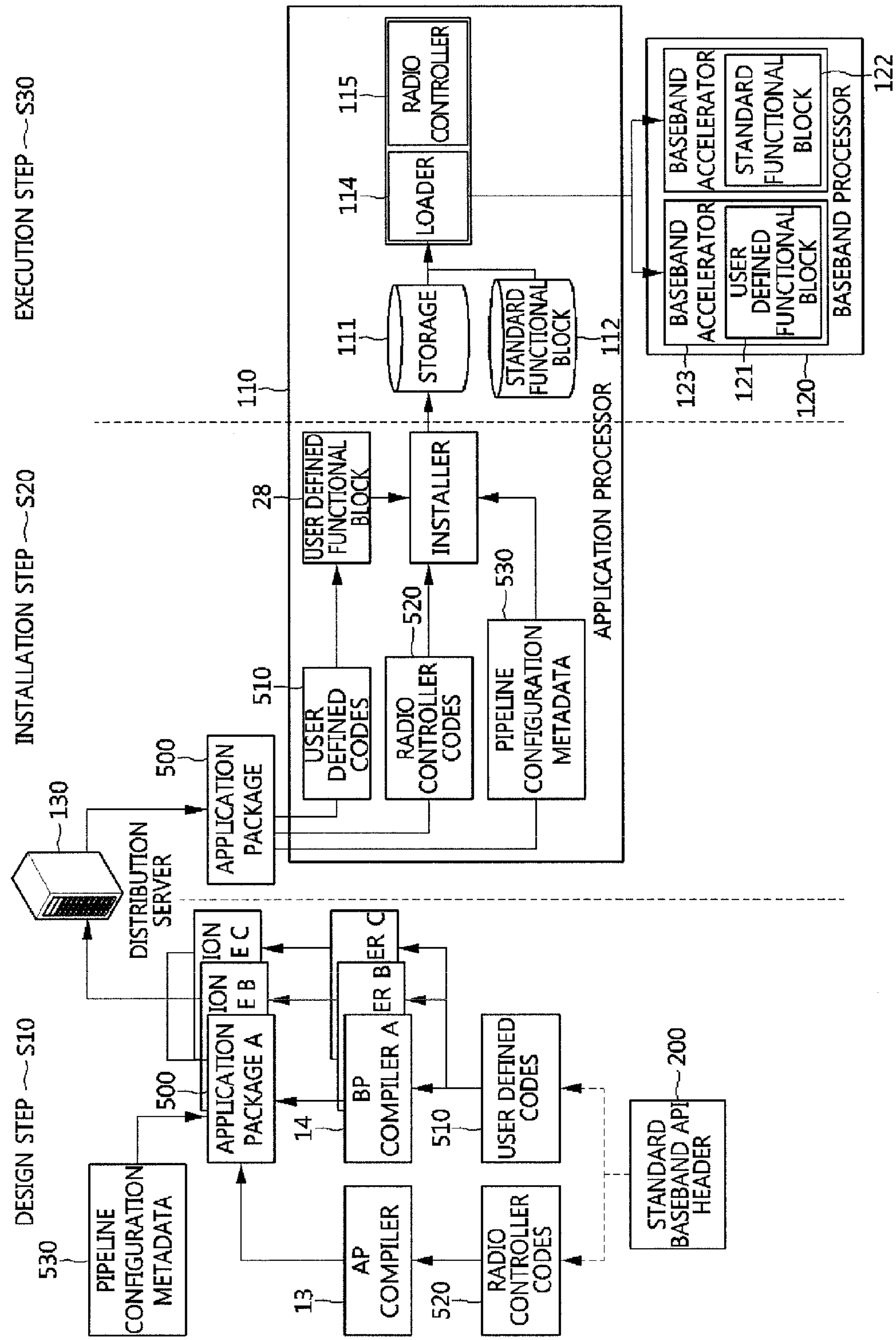

DESIGN STEP ~ S10
INSTALLATION STEP ~ S20
EXECUTION STEP ~ S30
530
PIPELINE CONFIGURATION METADATA
500
APPLICATION PACKAGE A
13
AP COMPILER
14
BP COMPILER A
520
RADIO CONTROLLER CODES
510
USER DEFINED CODES
200
STANDARD BASEBAND API HEADER
130
DISTRIBUTION SERVER
500
APPLICATION PACKAGE
510
USER DEFINED CODES
520
RADIO CONTROLLER CODES
530
PIPELINE CONFIGURATION METADATA
28
USER DEFINED FUNCTIONAL BLOCK
INSTALLER
APPLICATION PROCESSOR
110
111
STORAGE
112
STANDARD FUNCTIONAL BLOCK
114
LOADER
115
RADIO CONTROLLER
BASEBAND ACCELERATOR
USER DEFINED FUNCTIONAL BLOCK
BASEBAND ACCELERATOR
STANDARD FUNCTIONAL BLOCK
BASEBAND PROCESSOR
122
123
121
120

FIG. 3

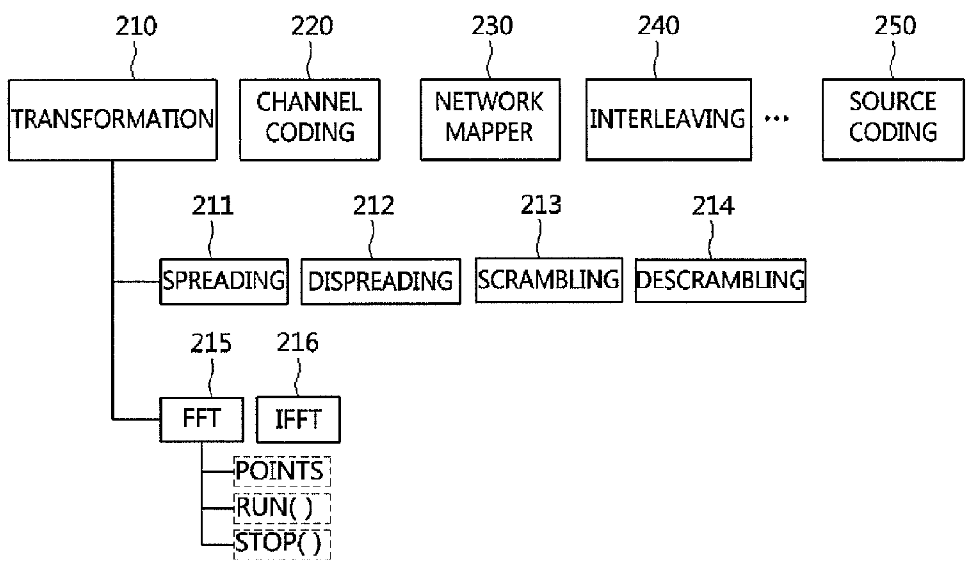
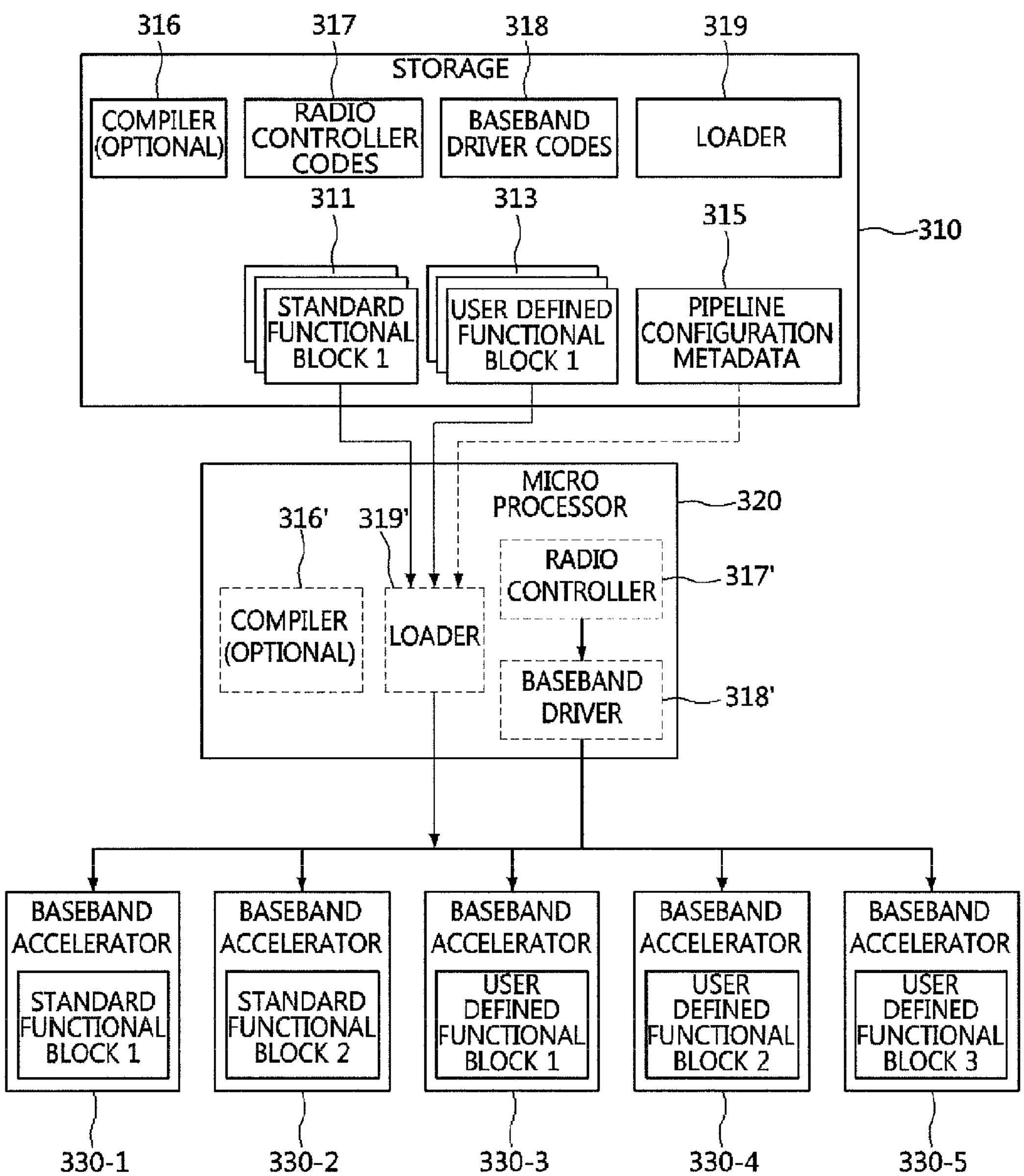

210
TRANSFORMATION
220
CHANNEL CODING
230
NETWORK MAPPER
240
INTERLEAVING
...
250
SOURCE CODING
211
SPREADING
212
DISPREADING
213
SCRAMBLING
214
DESCRAMBLING
215
FFT
216
IFFT
POINTS
RUN( )
STOP( )

FIG. 4



316
317
318
319
STORAGE
COMPILER (OPTIONAL)
RADIO CONTROLLER CODES
BASEBAND DRIVER CODES
LOADER
311
313
315
310
STANDARD FUNCTIONAL BLOCK 1
USER DEFINED FUNCTIONAL BLOCK 1
PIPELINE CONFIGURATION METADATA
MICRO PROCESSOR
320
316'
319'
RADIO CONTROLLER
317'
COMPILER (OPTIONAL)
LOADER
BASEBAND DRIVER
318'
BASEBAND ACCELERATOR
STANDARD FUNCTIONAL BLOCK 1
BASEBAND ACCELERATOR
STANDARD FUNCTIONAL BLOCK 2
BASEBAND ACCELERATOR
USER DEFINED FUNCTIONAL BLOCK 1
BASEBAND ACCELERATOR
USER DEFINED FUNCTIONAL BLOCK 2
BASEBAND ACCELERATOR
USER DEFINED FUNCTIONAL BLOCK 3
330-1
330-2
330-3
330-4
330-5

FIG. 5

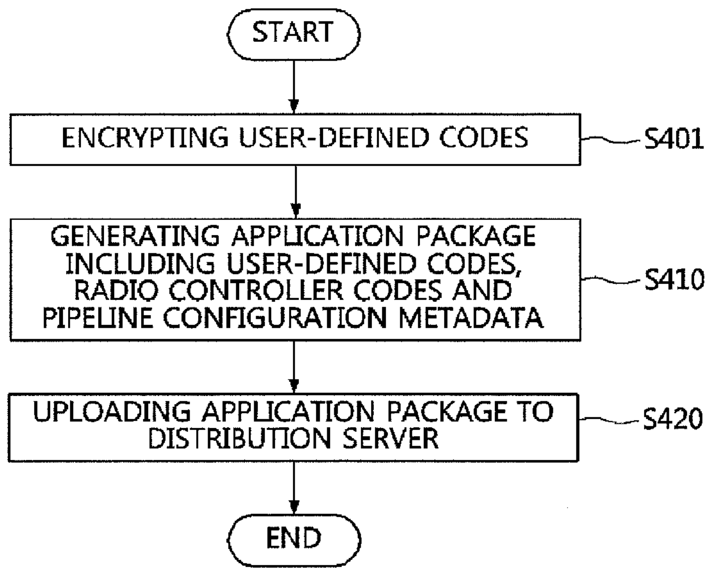

START
ENCRYPTING USER-DEFINED CODES
S401
GENERATING APPLICATION PACKAGE INCLUDING USER-DEFINED CODES, RADIO CONTROLLER CODES AND PIPELINE CONFIGURATION METADATA
S410
UPLOADING APPLICATION PACKAGE TO DISTRIBUTION SERVER
S420
END

FIG. 6

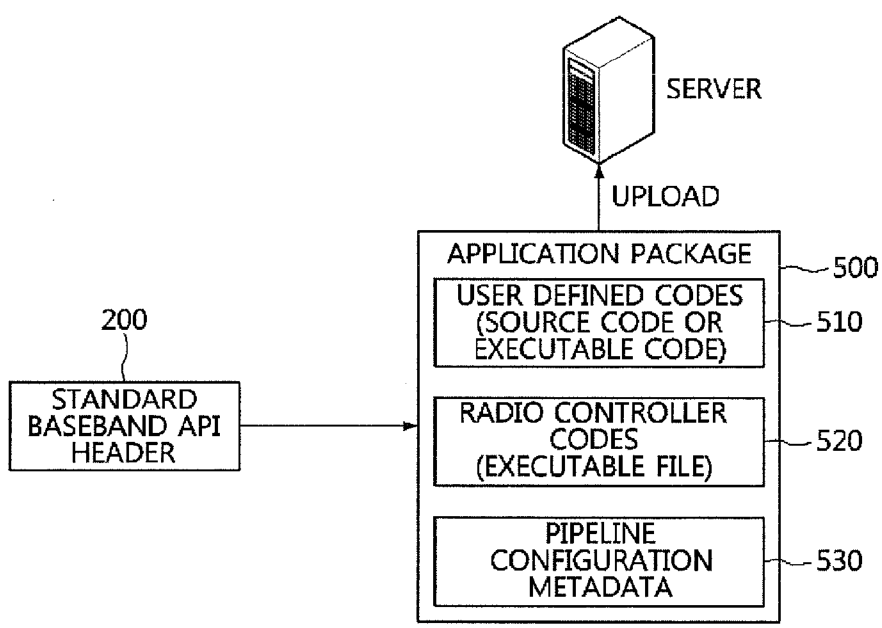

SERVER
UPLOAD
APPLICATION PACKAGE
500
USER DEFINED CODES (SOURCE CODE OR EXECUTABLE CODE)
510
RADIO CONTROLLER CODES (EXECUTABLE FILE)
520
PIPELINE CONFIGURATION METADATA
530
200
STANDARD BASEBAND API HEADER

FIG. 7

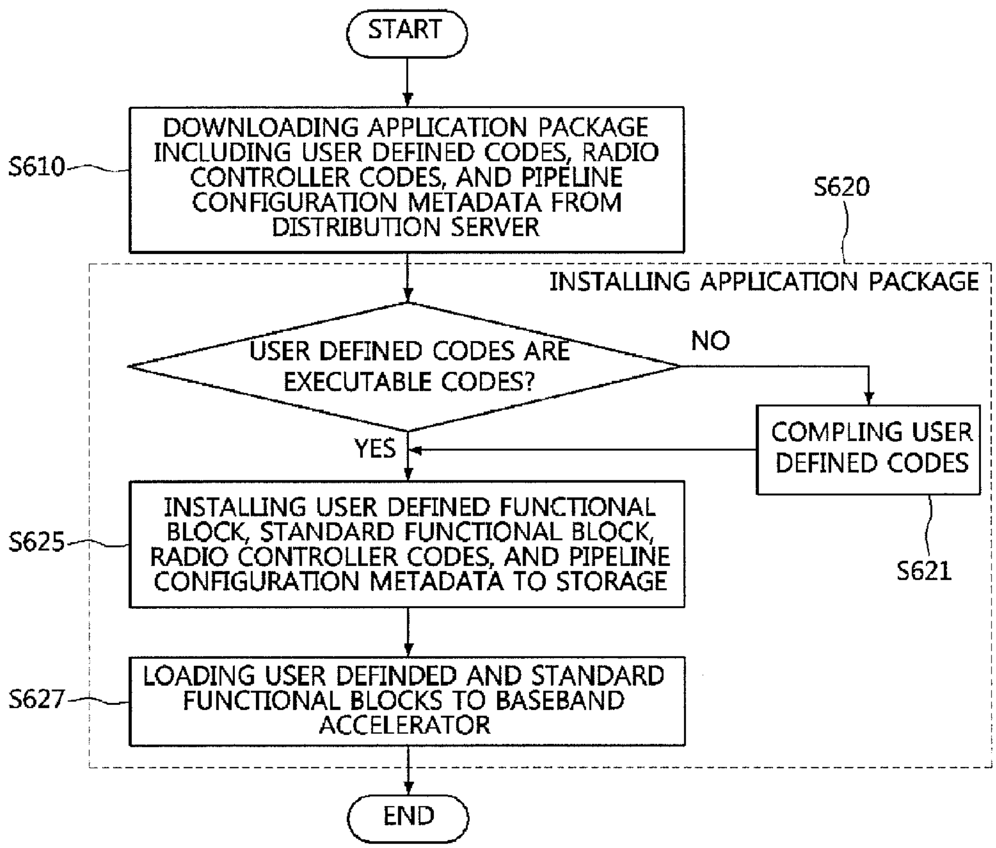
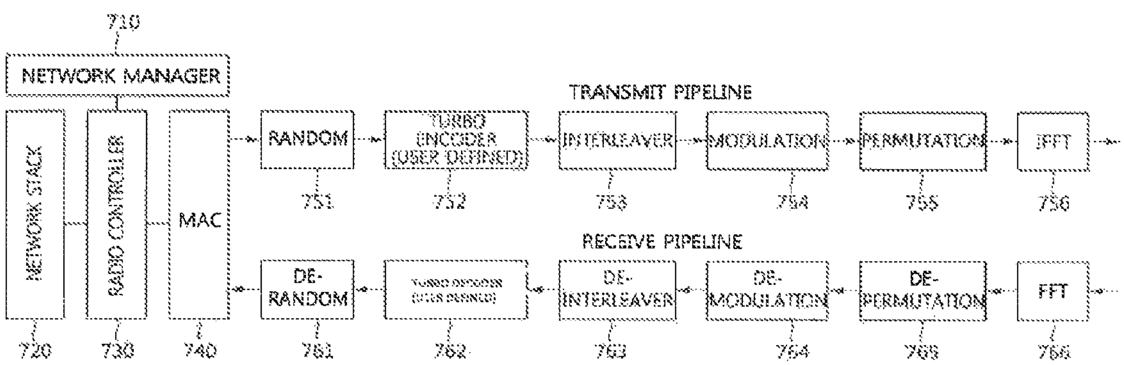

START
DOWNLOADING APPLICATION PACKAGE INCLUDING USER DEFINED CODES, RADIO CONTROLLER CODES, AND PIPELINE CONFIGURATION METADATA FROM DISTRIBUTION SERVER
S610
S620
INSTALLING APPLICATION PACKAGE
USER DEFINED CODES ARE EXECUTABLE CODES?
NO
COMPLING USER DEFINED CODES
YES
INSTALLING USER DEFINED FUNCTIONAL BLOCK, STANDARD FUNCTIONAL BLOCK, RADIO CONTROLLER CODES, AND PIPELINE CONFIGURATION METADATA TO STORAGE
S625
S621
LOADING USER DEFINDED AND STANDARD FUNCTIONAL BLOCKS TO BASEBAND ACCELERATOR
S627
END

FIG. 8



710
NETWORK MANAGER
TRANSMIT PIPELINE
NETWORK STACK
RADIO CONTROLLER
MAC
RANDOM
TURBO ENCODER (USER DEFINED)
INTERLEAVER
MODULATION
PERMUTATION
IFFT
751
752
753
754
755
756
RECEIVE PIPELINE
DE-RANDOM
DE-INTERLEAVER
DE-MODULATION
DE-PERMUTATION
FFT
720
730
740
761
762
763
764
765
766

FIG. 9

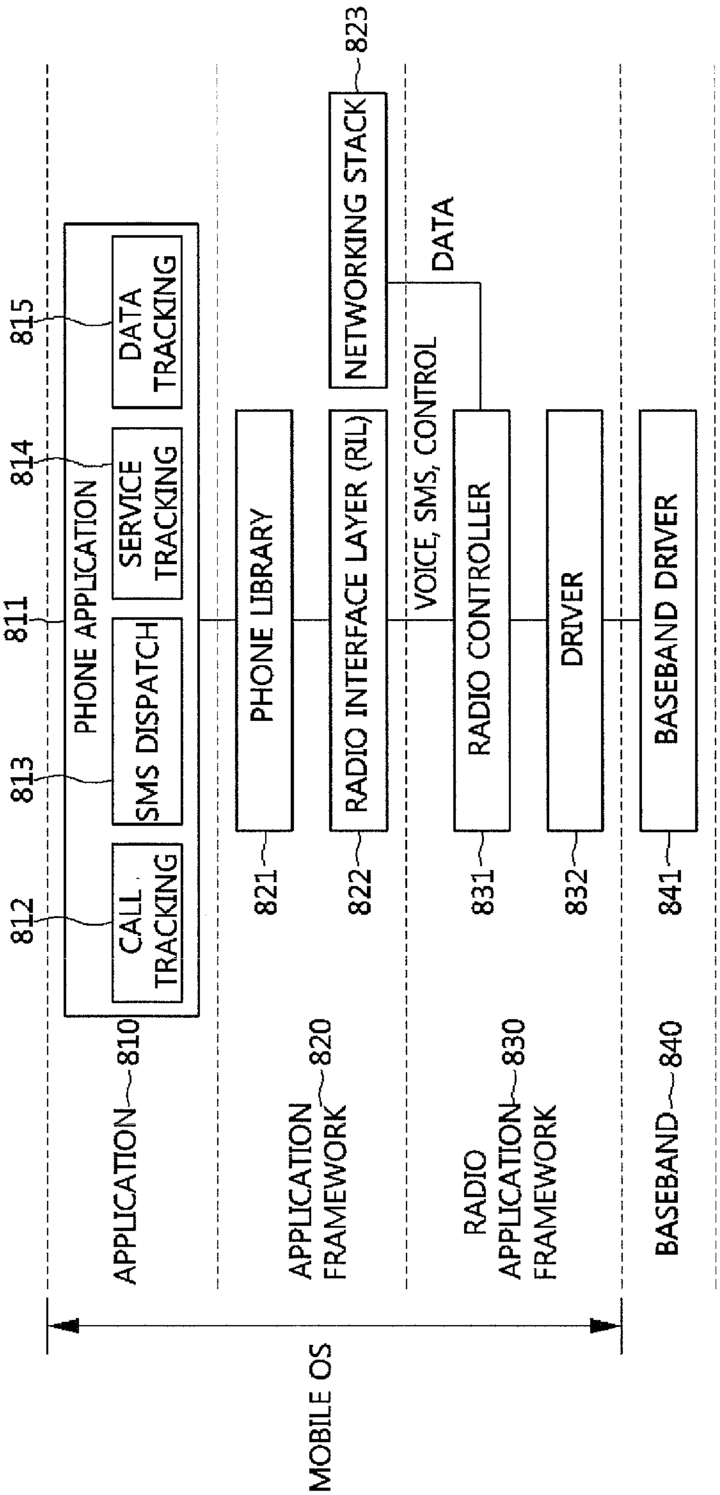
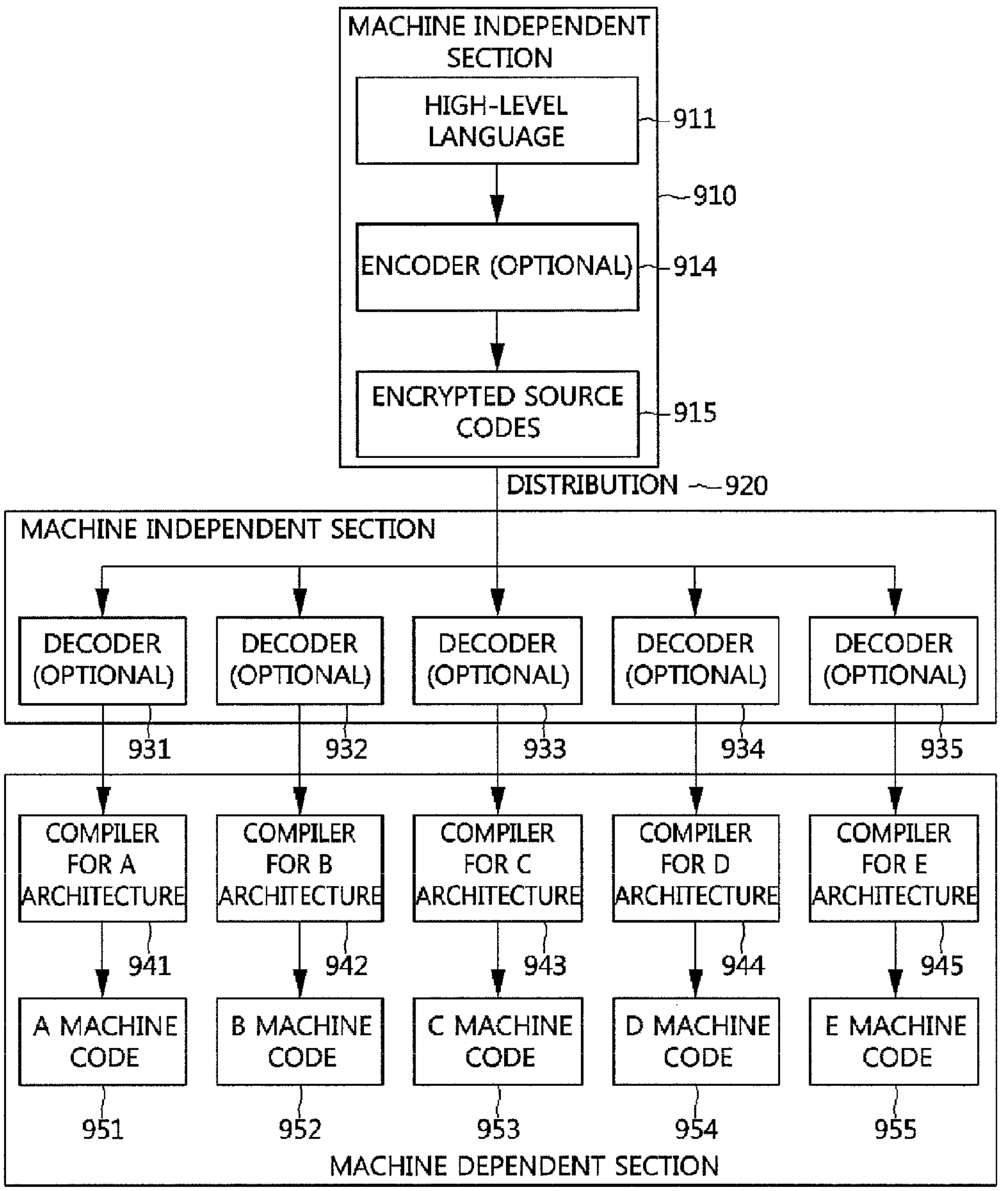

MOBILE OS
APPLICATION 810
APPLICATION FRAMEWORK 820
RADIO APPLICATION FRAMEWORK 830
BASEBAND 840
PHONE APPLICATION 811
CALL TRACKING 812
SMS DISPATCH 813
SERVICE TRACKING 814
DATA TRACKING 815
PHONE LIBRARY 821
RADIO INTERFACE LAYER (RIL) 822
NETWORKING STACK 823
VOICE, SMS, CONTROL
DATA
RADIO CONTROLLER 831
DRIVER 832
BASEBAND DRIVER 841

FIG. 10



MACHINE INDEPENDENT SECTION
HIGH-LEVEL LANGUAGE
911
910
ENCODER (OPTIONAL)
914
ENCRYPTED SOURCE CODES
915
DISTRIBUTION
920
MACHINE INDEPENDENT SECTION
DECODER (OPTIONAL)
DECODER (OPTIONAL)
DECODER (OPTIONAL)
DECODER (OPTIONAL)
DECODER (OPTIONAL)
931
932
933
934
935
COMPILER FOR A ARCHITECTURE
COMPILER FOR B ARCHITECTURE
COMPILER FOR C ARCHITECTURE
COMPILER FOR D ARCHITECTURE
COMPILER FOR E ARCHITECTURE
941
942
943
944
945
A MACHINE CODE
B MACHINE CODE
C MACHINE CODE
D MACHINE CODE
E MACHINE CODE
951
952
953
954
955
MACHINE DEPENDENT SECTION

FIG. 11

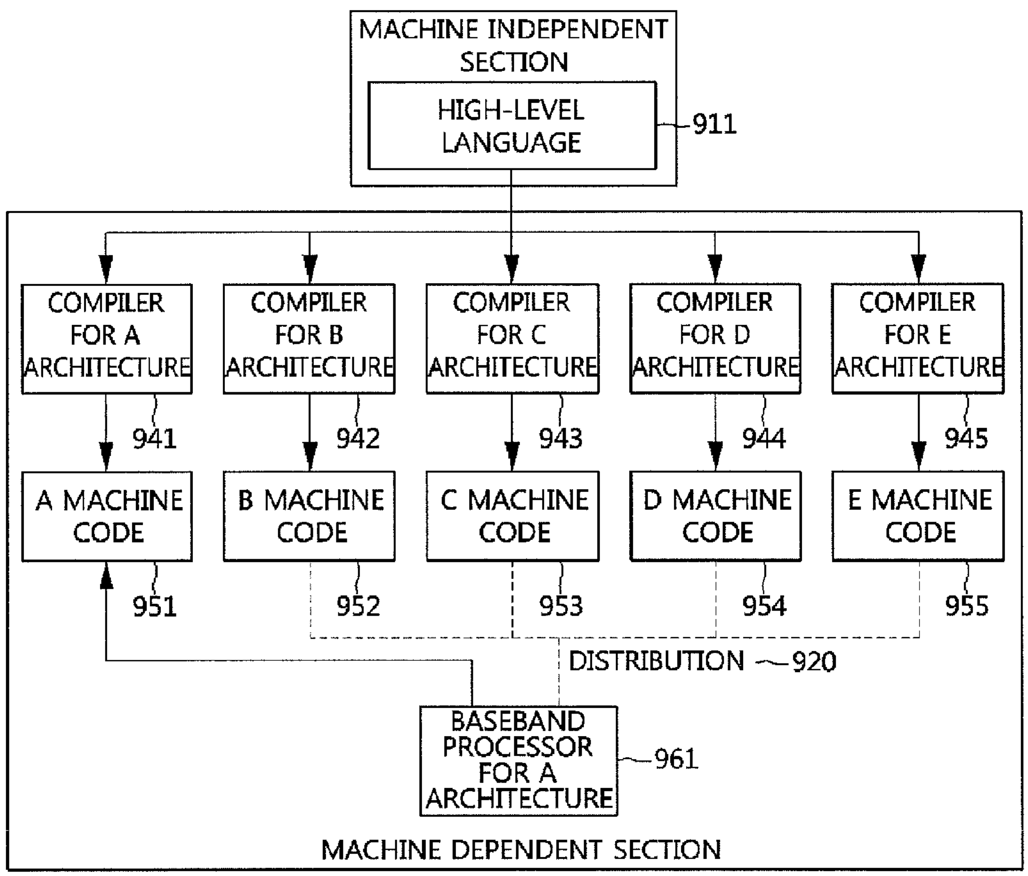
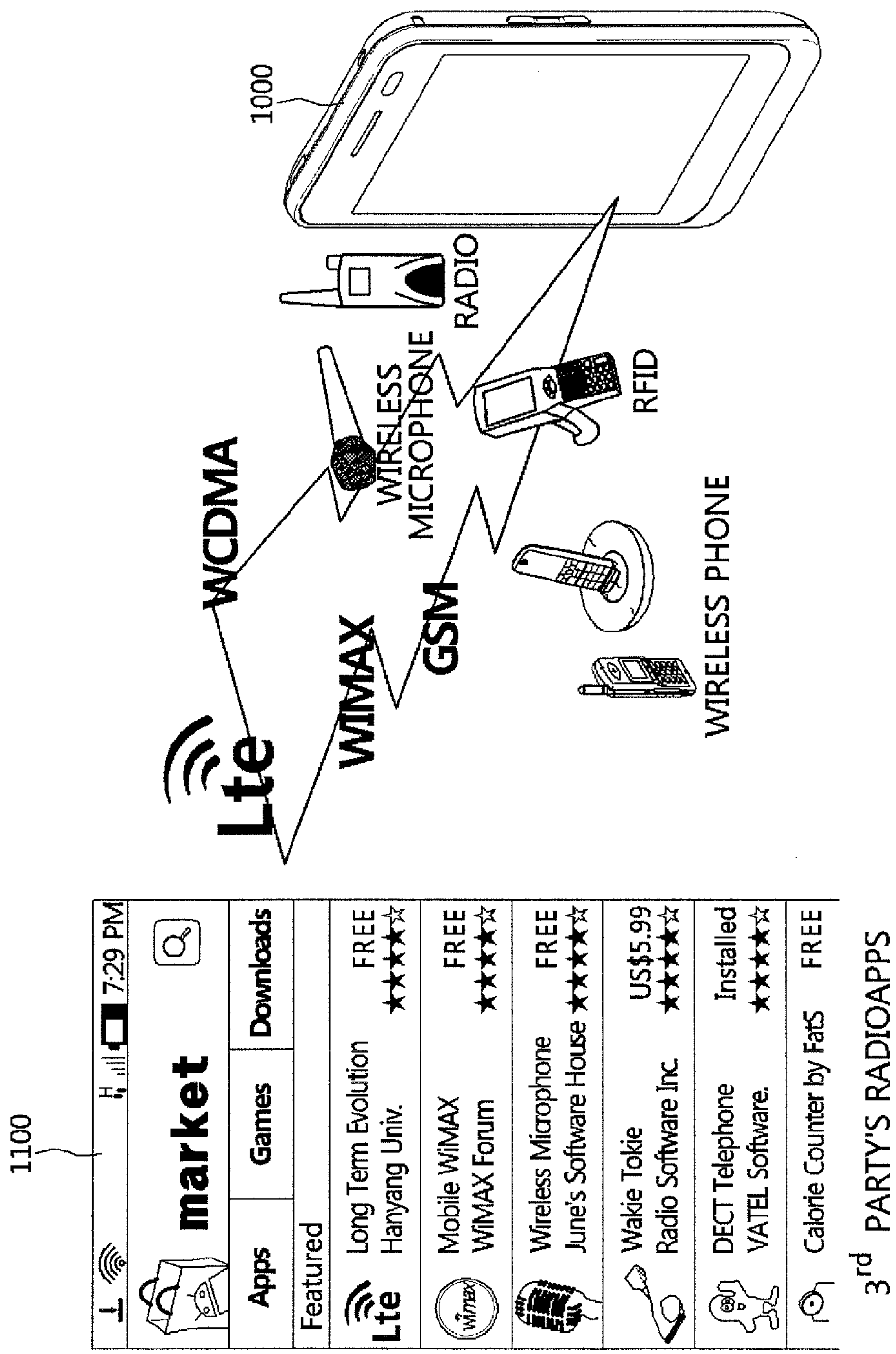

MACHINE INDEPENDENT SECTION
HIGH-LEVEL LANGUAGE
911
COMPILER FOR A ARCHITECTURE
COMPILER FOR B ARCHITECTURE
COMPILER FOR C ARCHITECTURE
COMPILER FOR D ARCHITECTURE
COMPILER FOR E ARCHITECTURE
941
942
943
944
945
A MACHINE CODE
B MACHINE CODE
C MACHINE CODE
D MACHINE CODE
E MACHINE CODE
951
952
953
954
955
DISTRIBUTION
920
BASEBAND PROCESSOR FOR A ARCHITECTURE
961
MACHINE DEPENDENT SECTION

FIG. 12


1000
1100
RADIO
WIRELESS MICROPHONE
RFID
WIRELESS PHONE
WCDMA
WiMAX
GSM
Lte
7:29 PM
market
Apps
Games
Downloads
Featured
Long Term Evolution
Hanyang Univ.
FREE
Mobile WiMAX
WiMAX Forum
FREE
Wireless Microphone
June's Software House
FREE
Wakie Tokie
Radio Software Inc.
US$5.99
DECT Telephone
VATEL Software.
Installed
Calorie Counter by FatS
FREE
3rd PARTY'S RADIOAPPS

SOFTWARE-DEFINED RADIO TERMINAL APPARATUS, AND METHOD FOR DISTRIBUTING AND INSTALLING RADIO APPLICATIONS

TECHNICAL FIELD

Example embodiments of the present invention relate in general to the field of software defined radio terminal apparatuses and a method of distributing and installing radio applications for the same, and more specifically to the field of a software defined radio terminal, in which the radio applications are executed independently of a modem chip embedded in the terminal, and a method of distributing and installing the radio applications for the same.

BACKGROUND ART

As communication technology advances, various new kinds of radio applications are being used as adapted for tastes and objectives of users. The most of radio applications, such as a Long Term Evolution (LTE), a Wide-band Code Division Multiple Access (WCDMA), a Worldwide Interoperability for Microwave Access (WiMAX), a Global System for Mobile Communications (GSM), may operate on radio terminals by interworking with a modem embedded in the radio terminal. a

In order to make it possible that a radio application controls the modem, a customized module should be developed based on understanding unique instructions of each modem designed by various modem manufactures or having various models. This situation leads to a result that a specific application can be executed on a specific modem designed by a specific manufacturer, or even on a specific model of modem designed by the specific manufacturer. To overcome the above-mentioned problem, different control instruction codes customized for various kinds of modems should be comprised in the radio application, or different executable file for each modem should be built and distributed.

However, since it is practically impossible to optimize the radio application to all the various kinds of modem hardware currently available in the market currently by the above-mentioned methods, there is a problem that a great manpower is needed to develop a radio application.

DISCLOSURE

Technical Problem

Accordingly, example embodiments of the present invention are provided to substantially obviate one or more problems due to limitations and disadvantages of the related art.

Example embodiments of the present invention provide a software defined radio terminal apparatus which can support a radio application to operate independently of a modem chip.

Example embodiments of the present invention also provide a method of distributing a radio application independent on a modem chip to the radio terminal apparatus.

Example embodiments of the present invention also provide a method of installing a radio application independent on a modem chip into the radio terminal apparatus.

Technical Solution

In some example embodiments according to the present invention, a radio terminal being configured according to a radio application is provided, wherein the radio terminal

includes a storage in which at least one functional block is installed, a compiler, a microprocessor, and at least one baseband accelerator, wherein the microprocessor is configured to read out codes including a radio controller layer transferring control commands for controlling the baseband accelerator and information to be transmitted from an upper layer to the baseband accelerator and transferring information received from the baseband accelerator to the upper layer and a baseband driver layer enabling an interface between the radio controller layer and the baseband accelerator from the storage, and to execute the codes, wherein the microprocessor is further configured to load the at least one functional block from the storage to the at least one baseband accelerator for performing the radio application, wherein the compiler is configured to compile the at least one functional block in form of source code into an executable code, and install the executable code into the storage, and wherein the at least one function block loaded into the at least one baseband accelerator includes a baseband control functional block controlling the at least one baseband accelerator in real time.

In another example embodiments according to the present invention, a method of distributing a radio application, the method may include encrypting user-defined codes defining functional blocks for implementing a specific radio application; generating an application package including the user-defined codes, radio controller codes configured to transfer control commands for controlling the functional blocks and information to be transmitted from an upper layer to the functional blocks, and to interface with an Operating System (OS) of a terminal, a pipeline configuration metadata specifying the functional blocks for implementing the specific radio application and connections between the functional blocks for implementing the specific radio application; and uploading the generated application package to an application distribution server.

In still another example embodiment according to the present invention, a method of installing a radio application, performed in a software defined radio terminal, the method may include downloading, from a distribution server, an application package including user-defined codes defining functional blocks for implementing the radio application, radio controller codes configured to transfer control commands for controlling the functional blocks for implementing the radio application and information to be transmitted from an upper layer to the functional blocks, and to interface with an Operating System (OS) of a terminal, a pipeline configuration metadata specifying the functional blocks for implementing the specific radio application and connections between the functional blocks for implementing the specific radio application; installing the radio controller codes and the user-defined codes into a storage of the terminal, by referring the pipeline configuration metadata; and decoding the use-defined codes when the user-defined codes are encrypted.

Advantageous Effects

When a software defined radio terminal apparatus according to the present invention, as described above, is used, the same application may be executed in terminals having modem chips with different structures thorough a standard baseband API. Also, by providing various digital signal processing algorithms needed in wireless digital communication based on the standard baseband API for optimal digital signal processing, manufacturers of modem hardware may select hardware or software implementation according to complexity and power consumption of each block included in the standard baseband API, and producers of radio applications may produce radio applications which are independent of the modem hardware using the standard baseband API. Also, various extensions of the baseband API may be possible by providing user-defined type blocks to implement functions not included in the standard baseband API.

DESCRIPTION OF DRAWINGS

FIG. **1** is a view to show a procedure in a case that user-defined codes included in the application are distributed and executed in source code form;

FIG. **2** is a view to show a procedure in a case that the user-defined codes are distributed and executed in executable codes;

FIG. **3** is a conceptual diagram to an example standard baseband interface according to an example embodiment of the present invention;

FIG. **4** is a block diagram to show a constitution of software-defined radio terminal according to an example embodiment of the present invention;

FIG. **5** is a flow chart to show a procedure of distributing a radio application according to an example embodiment of the present invention;

FIG. **6** is a block diagram to show a procedure of generating a radio application according to an example embodiment of the present invention;

FIG. **7** is a flow chart to show a procedure of installing radio application according to an example embodiment of the present invention;

FIG. **8** is a block diagram to show an operation example of radio application in a terminal according to an example embodiment of the present invention;

FIG. **9** is a block diagram to show an operation example of radio application in a terminal according to other example embodiment of the present invention;

FIG. **10** is a block diagram to explain a procedure of distributing radio application including user defined codes in source code form according to an example embodiment of the present invention;

FIG. **11** is a block diagram to show a procedure of distributing radio application including user defined codes in source code form according to another example embodiment of the present invention; and

FIG. **12** is a conceptual diagram to show an example of on-line store trading radio applications according to the present invention.

MODES OF THE INVENTION

Example embodiments of the present invention are disclosed herein. However, specific structural and functional details disclosed herein are merely representative for purposes of describing example embodiments of the present invention, however, example embodiments of the present invention may be embodied in many alternate forms and should not be construed as limited to example embodiments of the present invention set forth herein.

Accordingly, while the invention is susceptible to various modifications and alternative forms, specific embodiments thereof are shown by way of example in the drawings and will herein be described in detail. It should be understood, however, that there is no intent to limit the invention to the particular forms disclosed, but on the contrary, the invention is to cover all modifications, equivalents, and alternatives falling within the spirit and scope of the invention. Like numbers refer to like elements throughout the description of the figures.

It will be understood that, although the terms first, second, etc. may be used herein to describe various elements, these elements should not be limited by these terms. These terms are only used to distinguish one element from another. For example, a first element could be termed a second element, and, similarly, a second element could be termed a first element, without departing from the scope of the present invention. As used herein, the term "and/or" includes any and all combinations of one or more of the associated listed items.

It will be understood that when an element is referred to as being "connected" or "coupled" to another element, it can be directly connected or coupled to the other element or intervening elements may be present. In contrast, when an element is referred to as being "directly connected" or "directly coupled" to another element, there are no intervening elements present. Other words used to describe the relationship between elements should be interpreted in a like fashion (i.e., "between" versus "directly between", "adjacent" versus "directly adjacent", etc.).

The terminology used herein is for the purpose of describing particular embodiments only and is not intended to be limiting of the invention. As used herein, the singular forms "a", "an," and "the" are intended to include the plural forms as well, unless the context clearly indicates otherwise. It will be further understood that the terms "comprises", "comprising,", "includes," and/or "including", when used herein, specify the presence of stated features, integers, steps, operations, elements, components, and/or groups thereof, but do not preclude the presence or addition of one or more other features, integers, steps, operations, elements, components, and/or groups thereof.

Unless otherwise defined, all terms (including technical and scientific terms) used herein have the same meaning as commonly understood by one of ordinary skill in the art to which this invention belongs. It will be further understood that terms, such as those defined in commonly used dictionaries, should be interpreted as having a meaning that is consistent with their meaning in the context of the relevant art and will not be interpreted in an idealized or overly formal sense unless expressly so defined herein.

It should also be noted that in some alternative implementations, the functions/acts noted in the blocks may occur out of the order noted in the flowcharts. For example, two blocks shown in succession may in fact be executed substantially concurrently or the blocks may sometimes be executed in the reverse order, depending upon the functionality/acts involved.

Hereinafter, preferred embodiments according to the present invention will be described in detail with reference to the accompanying drawings.

FIG. **1** and FIG. **2** are conceptual block diagrams to explain a constitution of a radio application and procedures from distribution and execution of the radio application according to the present invention, FIG. **1** is a view to show a procedure in a case that user-defined codes included in the application are distributed and executed in source code form, and FIG. **2** is a view to show a procedure in a case that the user-defined codes are distributed and executed in executable codes.

Referring to FIG. **1** and FIG. **2**, the procedure of distribution and execution of the radio application according to an example embodiment of the present invention may comprise three steps—a design step (S**10**), an installation step (S**20**), and an execution step (S**30**).

The design step (S**10**) is a step of producing the radio application. In the design step, a supplier of the radio application may generate a radio application package **500** including radio controller codes and user-defined codes for implementing the radio application by using a standard baseband application programming interface (API) header **200** defining a standard baseband interface.

At this time, the radio controller codes **520** may be included in the radio application package **500** in executable code form through a compiler **13**. Also, as shown in FIG. **1**, in a case that the user-defined codes are distributed in source code form, the user-defined codes may be distributed in encrypted source code form through an encryption procedure performed by an encoder **15**. If the user-defined codes **510** are distributed in source code form, the user-defined codes may be compiled in a terminal which will execute the user-defined codes, and thereby device-independency of the user-defined codes may be achieved.

Meanwhile, as shown in FIG. **2**, when the user-defined codes **510** may be distributed in executable codes which can be directly executed in terminal, one of various compilers **14** may compile the user-defined codes into executable codes suitable for an execution environment of the terminal, and make the executable codes being included in the application package **500**.

The radio application package **500** generated according to the above-described procedure may be uploaded to a distribution sever **130**, and then downloaded to a terminal desiring to use the corresponding radio application.

The installation step (S**20**) is a step of downloading the radio application package **500** stored in the distribution server **130**, and installing the radio application by using the downloaded radio application package **500**. At this time, the user-defined codes **510**, the radio controller codes **520** and the pipeline configuration metadata **530** included in the radio application package **500** may be installed in an application processor layer **110** or a baseband processor layer **120**.

Here, as shown in FIG. **1**, if the user-defined codes are in source code form, the user-defined codes may be complied and generated into at least one executable user-defined functional block **28** by a compiler **27**. If the user-defined codes are encrypted, the user-defined codes may be complied after being decoded by a decoder **29**. On the other hand, if the user-defined codes are in executable code customized for a terminal, the compiling shown in FIG. **2** is not necessary.

The execution step (S**30**) is a step of actual execution of the installed radio application, and the actual wireless communication may be performed by loading and executing the executable codes installed for processing radio signals through the application processor **110** and the baseband processor **120**, based on information within the radio application.

For example, when command instructing an execution of the radio application installed in terminal is received, a loader **114** may determine which blocks are needed for performing the radio application by referring to the pipeline configuration metadata **530**. Also, the radio controller **520** and the user-defined functional blocks **28** may be loaded from a storage **111** of terminal. Also, the loader **114** may load the radio controller codes **520** to the application processor **110** or the baseband processor **120**, and load the user-defined functional block **121** and standard functional block **122** into the baseband accelerator **123** by referring to the pipeline configuration metadata **530**.

FIG. **3** is a conceptual diagram to an example standard baseband interface according to an example embodiment of the present invention.

Referring to FIG. **3**, a standard baseband interface is an application programming interface (API) standardizing digital signal processing algorithms needed for baseband domain in modem, and the standard interfaces **210~250** and the standard functional blocks **211~214** are shown as an example.

As a type of the standard interface, the standard interface may include a transformation **210**, a channel coding **220**, a network mapper **230**, an interleaving **240**, and a source coding **250** and so on. Also, as standard functional blocks for the transformation **210**, a spreading **211**, a dispreading **212**, a scrambling **213**, a descrambling **214**, a Fast Fourier Transform (FFT) **215** and an Inverse Fast Fourier Transform (IFFT) **216** may be defined.

For example, Input/Out data through the FFT **215**, properties of the data, and member functions may be defined for the FFT **215**. Also, an object-oriented design of radio application may be made possible by assigning common properties to functional blocks having the same type.

Meanwhile, in the example embodiments of the present invention, a standard application programming interface (API) header file which is written in high-level language according to the above-described standard baseband interface may be used. Therefore, a developer of radio application may develop radio applications by referring to the standard interface API header.

An Example Embodiment of Constitution of Software-Defined Radio Terminal

FIG. **4** is a block diagram to show a constitution of software-defined radio terminal according to an example embodiment of the present invention.

Referring to FIG. **4**, a software-defined radio terminal according to an example embodiment of the present invention may comprise a storage **310** configured to store user-defined functional block codes **313**, a pipeline configuration metadata **315**, radio controller codes **317**, baseband driver codes **318**, and a loader **319**, a microprocessor **320** configured to read out a compiler **316**, the radio controller codes **317**, the baseband driver codes **319** and the loader **319** from the storage **310** and to execute them, and a plurality of baseband accelerators **330**.

Hereinafter, by referring to FIG. **4**, the constitution of the software-defined radio terminal according to an example embodiment of the present invention, and relation of connections between the components of the terminal will be explained in detail.

The standard functional blocks **311**, the user-defined functional blocks **313**, the pipeline configuration metadata **315**, the compiler **316**, the radio controller codes **317**, the baseband driver codes **318**, and the loader **319** may be stored in the storage **310**. Thus, the microprocessor **320** is configured to readout the codes from the storage and execute the codes.

Here, the user defined functional blocks **313**, the pipeline configuration metadata **315**, and the radio controller codes **317** may be downloaded from an application server and installed to the storage **310**.

In this case, the downloaded user-defined functional blocks may be in source code form, in intermediate representation (IR) form, or in executable code form. If the downloaded user-defined functional blocks are in source code form, the compiler **316** executed in the microprocessor **320** may compile the user-defined functional blocks into executable codes for the terminal and store the executable codes in the storage **310**. If the downloaded user-defined functional blocks are executable codes already compiled suitable for the terminal, the user-defined functional blocks may be installed in the storage **310** without any further converting procedures.

Here, the storage **310** may be implemented as a Non-Volatile memory such as flash memory device, or a Volatile memory such as D-RAM or S-RAM. The storage is a component storing the user-defined functional blocks **313**, the pipeline configuration metadata **315**, the compiler **316**, the radio controller codes **317**, the baseband driver codes **318**, and the loader **319**. Thus, the microprocessor is configured to readout the codes to be executed from the storage and execute the codes.

For example, volatile memory constituting the storage **310** is a component which may be mapped to a memory space (that is, an address space) of the microprocessor **320**, may readout the components to be executed (such as those of the radio controller layer and the baseband driver layer) from the non-volatile memory and store them in it, and may make the microprocessor being capable of executing them. Here, a 'layer' may mean a set of software modules or a set of functions in an aspect of software.

However, a case that non-volatile memory is directly mapped to the memory space of the microprocessor **320** is also possible, and in this case, the microprocessor may execute codes stored in non-volatile memory directly on it.

The standard functional blocks **311** may be functional blocks to support standardized signal processing functions (such as, a DFT, a IDFT, a FFT, a IFFT, a channel coding, and an interleaving), which have been written based on the predefined standard baseband interface. Therefore, the standard functional blocks **311** may be initially installed in the terminal according to the present invention, or provided to users through firmware or software upgrade.

The user-defined functional blocks **313** may be functional blocks which are provided by supplier of radio application as explained above, and are downloaded from the application server and installed to the storage **310** by the user.

The pipeline configuration metadata **315** may be at least one data file in predetermined format which describes connections between functional blocks needed for implementing a radio application desired to be executed, and initial values of attributes of each functional block.

On the other hand, the user-defined functional blocks **313** may include baseband digital signal processing function which is not implemented in the standard functional block. That is, the standard functional block may be defined in the standard baseband API header **200**, and the supplier of radio application may constitute the user-defined functional blocks **315** and the pipeline configuration metadata by referring the standard baseband API header **200**.

The radio controller **317'** may be a component performed by reading out radio controller codes installed in the storage and executing the radio controller codes by the microprocessor. The radio controller is executed not in real time, and has a role of receiving control commands suitable for radio signal according to each radio application and transferring them to the baseband accelerator by using the standard baseband interface.

Also, the radio controller **317'** may have a responsibility of interfacing between a user layer and the baseband layer. That is, the radio controller receives receive data from the baseband accelerator and transfers the received data to a network stack (omitted in FIG. **04**), and transfers transmit data from the network stack to the baseband accelerator. On the other hand, when context information are required to be transferred to upper layer, the context information may be transferred from corresponding functional block to the upper layer via the radio controller. Here, the upper layer may be a user application.

Here, the context information may be transferred by a context information interface, and the context information interface may be a predefined interface needed for transferring the context information generated in functional block wanting to transfer context information from the functional block to the upper layer, which is used by the radio controller.

The microprocessor **320** may be configured to read out the radio controller codes **317** for transferring control commands controlling the baseband accelerator **330** according to application to be executes from the storage **310**, and execute them. Also, the codes including the baseband layer may be read out from the storage **310** and executed by the microprocessor **320**. At this time, the baseband driver **318** may be configured to take a role of enabling interfacing between the radio controller and the baseband accelerator.

Also, the microprocessor **320** may perform reconfiguration of the baseband accelerator by downloading the user-defined functional blocks **313** into the baseband accelerator, so that various applications can be executed in the terminal of the present invention.

For this, as shown in FIG. **4**, at least one functional block **311** and **313** may be configured to be downloaded to the baseband accelerator **330** from the storage **310**. Here, the functional blocks needed for performing algorithm may be allocated in the baseband accelerator **334** via the loader **319'** by referring the pipeline configuration metadata **315**.

The loader **319'** may be a program which is loaded from the storage and executed by the microprocessor, and may be included in the baseband driver **318'** according to other example embodiment. That is, the loader **319'** may load all the standard functional blocks **311** and user-defined functional blocks **313** which are specified in the pipeline configuration metadata **315** into the baseband accelerator **330** and make them be executed by the baseband accelerator **330**.

Meanwhile, the functional blocks loaded to the baseband accelerator may include a baseband control functional block controlling the baseband accelerator in real time. In this case, the loader **319'** may configure a pipeline defining an operation sequence of the loaded functional blocks based on the pipeline configuration metadata, and transfer configuration information of the pipeline to the baseband control functional block so that the baseband control functional block controls the baseband accelerator according to the transferred pipeline configuration information.

Configuration of Radio Application and Distribution of Radio Application

Hereinafter, a configuration and a procedure of distributing radio application for a software defined radio terminal according to an example embodiment of the present invention will be explained.

FIG. **5** is a flow chart to show a procedure of distributing a radio application according to an example embodiment of the present invention, and FIG. **6** is a block diagram to show a procedure of generating a radio application according to an example embodiment of the present invention.

Referring to FIG. **5**, a procedure of distributing a radio application according to an example embodiment of the present invention may be configured to include a step of encrypting user-defined codes **S401**, a step of generating application package **S410**, and a step of distributing application package **S420**.

Also, the step of generating application package **S410** may include a step of generating and compiling user-defined codes **S411**, a step of generating and compiling radio controller codes **S413**, a step of generating pipeline configuration metadata, and a step of generating package **S417**.

Meanwhile, referring to FIG. **6**, the radio application according to an example embodiment of the present invention may be generated from an application package including user-defined codes **510**, radio controller codes **520**, pipeline configuration metadata **530**.

Hereinafter, referring to FIG. **5** and FIG. **6**, each step of the distribution procedure of radio application according to an example embodiment of the present invention will be explained in detail.

The step of encrypting user-defined codes S**401** is a step of encrypting the user-defined codes to be included in a radio application package. The user-defined codes may be distributed in source code form, in intermediate representation (IR) form, or in executable code form, according to selection of radio application provider. In the case that the user-defined codes are distributed in source code form, it is desirable that the user-defined codes are written in standard languages in order to be compiled in various terminals. Meanwhile, in the case that the user-defined codes are distributed in source code form, since source codes of the user-defined codes may be exposed, the user-defined codes may be encrypted before distribution in order to prevent exposure of source codes.

The step of generating application package S**410** is a step of generating a radio application package including radio application to be executed in a software defined radio terminal. The application package may comprise, as shown in FIG. **6**, the user-defined codes **510**, the radio controller codes **520**, and the pipeline configuration metadata **530**.

Here, the user-defined codes **510** are codes defining functional block needed for implementing a radio application to be executed, and the radio controller codes **520** are codes written for controlling functional blocks needed for implementing the radio application to be executed. Also, the functional blocks defined by the user-defined codes are related to implementations of digital signal processing functions which are not implemented in the standard functional blocks defined in the standard baseband API header **200**.

On the other hand, the user-defined codes **510** may be constituted as one of codes executable directly in baseband accelerator of the terminal which the application package **500** is installed to, codes in source code form which needs to be compiled for execution, and executable codes.

Therefore, if the user-defined codes are in executable code form, the user-defined codes may be codes compiled by various compilers for various terminals.

In the radio controller codes **520**, codes for interfacing with an operation system of the terminal, and for controlling functional blocks needed to implement a radio application demanded. The radio controller codes **520** may be codes complied into executable codes by a compiler.

Meanwhile, the pipeline configuration metadata **530** may define functional blocks needed for implementing corresponding radio application, and connections between the functional blocks. Also, the pipeline configuration metadata **530** may include information on connections between the standard functional blocks included in the standard baseband API header **200** and the functional blocks defined by the user defined codes **510**, and information on initial configuration values for attributes of each of the functional blocks.

The user-defined codes **510**, the radio controller codes **520**, and the pipeline configuration metadata **530**, which have been generated in the above-described manner, may be uploaded to a server, and may be downloaded to the terminal wanting to use the corresponding radio application and installed to the terminal, in form of application package **500**.

In the step of distributing application package S**420**, the application package which has been in the above-described manner may be uploaded to a radio application distribution server, and downloaded to a software defined radio terminal wanting the corresponding radio application.

An Example Embodiment of a Method of Installing Radio Application

Hereinafter, a procedure of installing radio application according to an example embodiment of the present invention will be explained.

FIG. **7** is a flow chart to show a procedure of installing radio application according to an example embodiment of the present invention.

Referring to FIG. **7**, the procedure of installing radio application according to an example embodiment of the present invention may be configured to include a step of downloading application package S**610** and a step of installing application package S**620**.

Hereinafter, referring to FIG. **7**, each step of the installation procedure of radio application according to an example embodiment of the present invention will be explained in detail.

The step of downloading application package S**610** is a step of downloading radio application to be executed in software defined radio terminal from a distribution server. In the step of downloading application package S**610**, as shown in FIG. **6**, the application package **500** comprising the user defined codes **510**, the radio controller codes **520**, and the pipeline configuration metadata **530** may be downloaded from the distribution server to the software defined radio terminal.

The step of installing application package S**620** is a step of installing the application package downloaded from the distribution server to the terminal as a form executable by the terminal, and may include a step of compiling the user defined codes S**621**, a step of installing the compiled user defined codes to the storage S**625**, and a step of loading the user defined functional blocks S**627**.

The step of compiling the user defined codes S**621** is a step of compiling the user defined codes into codes executable directly in the baseband accelerator of the terminal in the case that the user defined codes included in the downloaded application package **500** are not codes executable directly in the baseband accelerator **330** but source codes, and generating the user defined functional blocks. Also, if the user defined codes are encrypted, the user defined codes are compiled after being decoded in the step S**621**.

Also, the step of installing the compiled user defined codes to the storage S**625** is a step of installing the pipeline configuration metadata **530** included in the downloaded application package **500**, the user defined functional blocks defined by the user defined codes **510**, the radio controller codes **520**, and the standard functional block which include standard command instruction codes based on the predefined standard baseband interface to the storage of the terminal.

The step of loading the user defined functional blocks S**627** is a step of loading the user defined functional blocks defined by the user defined functional blocks included in the downloaded radio application package **500** directly to the baseband accelerator **330**. At this time, if the user defined codes **510** are codes executable for the baseband accelerator **330**, the user defined functional blocks defined by the user defined codes **510** may be loaded to the baseband accelerator **330** directly without the step of compiling user defined codes S**621**.

FIG. **8** is a block diagram to show an operation example of radio application in a terminal according to an example embodiment of the present invention.

Referring to FIG. **8**, a constitution of a pipeline depicting operation procedures of functional blocks is shown, when a radio application adopting an Orthogonal Frequency Division Multiplexing (OFDM) is implemented in a terminal without a separate voice channel.

In the example of FIG. **4**, a turbo encoder **752** and a turbo decoder **762** are implemented in the form of user defined functional block, other blocks **751**, **753~756** of a transmit pipeline **750**, and other blocks **761**, **763~766** of a receive pipeline **760** are implemented in the form of standard functional block.

Meanwhile, the transmit pipeline may process data transmitted by a MAC **740**, and the receive pipeline may process receive data and transmit the processed data to the MAC **740**. Here, the radio controller **730** may take a role of exchanging data between the MAC **640** and the network stack **720**. Also, the radio controller **730** may provide interfaces corresponding to control commands of a network manager **710** embedded in an operation system (OS), and thereby may receive the control commands from the network manager **710**. The network manager **710** may be configured to present context information on radio signals such as transmit/receive signal qualities and a signal strength to an user by visualizing them, or to transfer control information such as information on access channel and radio signal encryption algorithm selected by the user to the radio controllers, so as to perform controlling radio signal according to intention of the user.

FIG. **9** is a block diagram to show an operation example of radio application in a terminal according to other example embodiment of the present invention.

Referring to FIG. **9**, an operation example of radio application implemented in a terminal with a separate voice channel.

Hereinafter, an interworking operation between a radio controller and internal functions of a mobile operation system operating in an application processor will be explained by referring to FIG. **9**.

Generally, in the mobile OS, a phone application may perform functions of telephone such as transmitting and receiving voice of short messaging service (SMS) messages in the terminal. As a usual, a call tracking function **812** which tracks call history and notifies it to a user in addition to voice call function, a SMS dispatch function **813** of transmitting and receiving SMS messages, and a data tracking function **815** of notifying an amount of data transmitted and received may exist within the phone application. These functions of the phone application **811** may be implemented based on a phone library **821** provided by the mobile OS, and the phone library **821** may transfer commands related to control on a baseband processor **841** to a radio interface layer (RIL) layer **822**.

A radio controller **831** may transfer signal for controlling the baseband processor **841** according to a wireless network control signal and a voice control signal of the mobile OS **800**. Also, the radio controller **831** may transmit voice data received from the baseband processor **841** to the phone application **811** and receive voice data received from the phone application **811** to the baseband processor **841**, when signals transmitted to and received from the baseband processor **841** are voice data. Otherwise, the radio controller **831** may transmit data received from the baseband processor **841** to a network stack **823** and receive data received from the network stack **823** to the baseband processor **841**, when signals transmitted to and received from the baseband processor **841** are packet data. Thereby, voice call function and wireless networking function may be provided to the user of the terminal at the same time.

Also, the radio controller may further include some upper layer functions of a MAC according to radio signal supported by a radio application. Referring to FIG. **5**, by connecting the radio controller **831** and the RIL **822**, an application framework **820** and a radio application framework may be configured so that the baseband processor **841** is controlled by the radio controller **831** according to control commands of the RIL **822**.

Accordingly, by connecting the radio controller customized and prepared for each radio application and the RIL **822**, a phone application independent on the radio application may control the baseband processor **841** dependent on the radio application via the radio controller **831**. Therefore, the above-described functions of phone application may be performed persistently without any change of the phone application, even when the radio application is changed.

FIG. **10** is a block diagram to explain a procedure of distributing radio application including user defined codes in source code form according to an example embodiment of the present invention.

Referring to FIG. **10**, the user defined codes **911** may be written in high-level language such as C or C++ during development of the radio application. Optionally, the user defined codes may be converted into encrypted source codes **915** by an encoder **914**.

The encrypted source codes **915** generated in the above-described manner may be distributed to each terminal as included in radio application package. In the procedure of installation to the terminal, the encrypted source codes may be converted to machine codes **951~955** executable in a modem hardware embedded in the terminal by a decoder **930** and compilers **941~945**. Since the compilers **941~945** are required to generate machine codes optimized for a modem hardware embedded in the terminal, the compilers **941~945** are dependent on the modem hardware. Thus, suppliers of modem hardware may produce compilers optimized to their modem hardware, and provide them to radio application developers.

FIG. **11** is a block diagram to show a procedure of distributing radio application including user defined codes in source code form according to another example embodiment of the present invention.

Referring to FIG. **11**, the user defined codes **911** may be written in high-level language such as C or C++ during development of the radio application, may be compiled into executable machine codes **951~955** by one of compilers **941~945**, suitable for corresponding baseband processor. These machine codes **951~955** may be packaged to respective radio application package for each, and the radio application packages may be uploaded to a radio application server. The terminal may download the radio application operable in its baseband processor **961**. Thus, suppliers of modem hardware may produce compilers **941~945** optimized to their modem hardwares, and provide them to radio application developers.

FIG. **12** is a conceptual diagram to show an example of on-line store trading radio applications according to the present invention.

Referring to FIG. **12**, the software defined radio terminal **1000** according to an example embodiment of the present invention may select one of radio applications supporting such as Long term Evolution (LTE), Wideband Code Division Multiple Access (WCDMA), Worldwide Interoperability for Microwave Access (WiMAX), Global System for Mobile Communications (GSM), and Radio-Frequency Identification (RFID) in the on-line store **1110**, download the selected radio application and operate according to the communication mode of the downloaded radio application independently on the modem chip embedded in the terminal. Also, radio applications which can be selected by the terminal may include a radio application making the terminal operate as a walkie-talkie, a wireless microphone, or a wireless phone.

While the example embodiments of the present invention and their advantages have been described in detail, it should be understood that various changes, substitutions and alterations may be made herein without departing from the scope of the invention.

The invention claimed is:

1. A radio terminal being configured according to a radio application,

wherein the radio terminal includes a nontransitory storage in which at least one functional block is installed, a compiler, a microprocessor, and at least one baseband accelerator,

wherein the microprocessor is configured to read out codes including a radio controller layer transferring control commands for controlling the baseband accelerator and information to be transmitted from an upper layer to the baseband accelerator and transferring information received from the baseband accelerator to the upper layer and a baseband driver layer enabling an interface between the radio controller layer and the baseband accelerator from the storage, and to execute the codes,

wherein the microprocessor is further configured to load the at least one functional block from the storage to the at least one baseband accelerator for performing the radio application,

wherein a compiler is configured to compile the at least one functional block in form of source code into an executable code, and install the executable code into the storage, and

wherein the at least one function block loaded into the at least one baseband accelerator includes a baseband control functional block controlling the at least one baseband accelerator in real time,

wherein the at least one functional block is a standard functional block in which standard instruction commands defined based on a standard baseband interface are specified, or an user-defined functional block provided from a supplier of the radio application,

wherein the microprocessor loads a loader configured to load the at least one functional block from the storage and relocate the at least one functional block based on predefined pipeline configuration metadata, and to execute the loader, and

wherein the loader configures a pipeline defining an operation sequence of the at least one functional block loaded based on the pipeline configuration metadata, and transfers configuration information of the pipeline to the baseband control functional block, and the baseband control functional block controls the at least one baseband accelerator in accordance with the pipeline.

2. The terminal of claim **1**, wherein the radio controller layer, the user-defined functional block, and the pipeline configuration metadata are downloaded from an application server, and installed to the terminal.

3. The terminal of claim **2**, further include a decoder decoding the user-defined functional block in source code form which is downloaded from the application server as encrypted.

4. The terminal of claim **1**, wherein the standard functional block is defined by a standard baseband application programming interface (API) header file.

5. The terminal of claim **4**, wherein the user defined functional block includes at least one baseband digital signal processing function which is not implemented in the standard functional block defined by the standard baseband application programming interface (API) header file.

6. The terminal of claim **5**, wherein the pipeline configuration metadata includes information on connections between the standard functional block defined by the standard baseband application programming interface (API) header file and the user-defined functional block, and information on initial configuration values for attributes of each of the functional blocks.

7. A processor-implemented method of distributing a radio application, the method comprising:

encrypting user-defined codes defining functional blocks for implementing a specific radio application;

generating an application package including the user-defined codes, radio controller codes configured to transfer control commands for controlling the functional blocks and information to be transmitted from an upper layer to the functional blocks, and to interface with an Operating System (OS) of a terminal, a pipeline configuration metadata specifying the functional blocks for implementing the specific radio application and connections between the functional blocks for implementing the specific radio application; and

uploading the generated application package to an application distribution server,

wherein the application package is downloaded to a software-defined radio (SDR) terminal comprising a microprocessor and at least one baseband accelerator, and

wherein the radio controller code is executed by the microprocessor, and the function blocks are loaded to the at least one baseband accelerator in order to re-configure the at least one baseband accelerator.

8. The method of claim **7**, wherein the user-defined codes are in source code form, or in executable code form executable in the terminal.

9. The method of claim **7**, wherein the functional block defined by the user-defined code is related to implementation of baseband digital signal processing function which is not implemented in the standard functional block defined by the standard baseband application programming interface (API) header file.

10. The method of claim **7**, wherein the pipeline configuration metadata includes information on connections between the standard functional block defined by the standard baseband application programming interface (API) header file and the functional block defined by the user-defined code, and information on initial configuration values for attributes of each of the functional blocks.

11. A processor-implemented method of installing a radio application, performed in a software defined radio terminal comprising a microprocessor and at least one baseband accelerator, the method comprising:

Downloading, from a distribution server, an application package including user-defined codes defining functional blocks for implementing the radio application, radio controller codes configured to transfer control commands for controlling the functional blocks for implementing the radio application and information to be transmitted from an upper layer to the functional blocks, and to interface with an Operating System (OS) of a terminal, a pipeline configuration metadata specifying the functional blocks for implementing the specific radio application and connections between the functional blocks for implementing the specific radio application;

installing the radio controller codes and the user-defined codes into a nontransitory storage of the terminal, by referring the pipeline configuration metadata; and decoding the use-defined codes when the user-defined codes are encrypted,

wherein the radio controller code is executed by the microprocessor, and the function blocks are loaded to the at least one baseband accelerator in order to re-configure the at least one baseband accelerator.

12. The method of claim **11**, wherein, when the user-defined codes are not executable codes for a baseband accelerator of the terminal, the installing the radio controller codes and the user-defined codes into a storage of the terminal further includes compiling the user-defined codes into executable codes for the baseband accelerator, and storing the compiled executable codes in the storage.

13. The method of claim **11**, wherein the functional block defined by the user-defined codes is related to implementation of baseband digital signal processing function which is not implemented in standard functional blocks defined by a standard baseband application programming interface (API) header file.

14. The method of claim **13**, wherein the pipeline configuration metadata includes information on connections between the standard functional block defined by the standard baseband application programming interface (API) header file and the functional block defined by the user-defined code, and information on initial configuration values for attributes of each of the functional blocks.

* * * * *